

Fluid Dynamics with Cryogenic Fluid Transfer in Space

Completed Technology Project (2013 - 2014)



Project Introduction

The main objective for this project is to build an accurate line chill-down database under an actual space microgravity condition with a duration long enough to cover the complete chill down characteristics of a fluid transfer line. The secondary objective is to demonstrate a non-intrusive method to determine a tank fill level based on vibration modes from the NASA Kennedy Space Center Lead Zirconium Titanate (PZT) system.

During chilldown of cryogenic fluid tanks and lines, the interface between the liquid and vapor rapidly changes. Understanding these rapid changes is key to understanding the thermal efficiencies of cryogenic fluid transfer in microgravity. In order to demonstrate transfer line chilldown, you must drain the storage tank. Draining a fluid storage tank in microgravity is a complex task that can be solved with elegant surface tension features inside the tank. Draining a tank during a transfer also presents opportunities for secondary data gathering on determining the fill level of the tank.

Kennedy Space Center (KSC) researchers have developed a unique method to determine a tank fill level based on the tank's response to vibration input using PZT sensors/ actuators. This can also yield information on the health of the tank. It has been demonstrated in microgravity using water for short durations produced by parabolic aircraft flights. This demonstration will increase its applicability to cryogenic fluids and rapid draining of tanks.

Anticipated Benefits

By providing initial transfer line chilldown and boiling heat transfer data, this project will aid the design of the Cryogenic Propellant Storage and Transfer (CPST) Technology Demonstration Mission. The data will be used by CPST to understand and design the transfer line chilldown process in microgravity. Similarly, it could be used by Space Launch System (SLS) to understand the chilldown of the upper stage engine feedlines.

If the fill level method is determined to be successful, it will provide an alternative method for determining the fill level of various tanks externally to the tank.

Reliable Fluid and cryogenic propellant transfer and storage and high performance fluid and propellant tanks (low weight and high reliability) greatly lower costs and increases in safety for extended space missions.

Many commercial space companies have openly discussed the transfer of cryogenic propellants on orbit. Understanding the gravitational parameters with heat transfer and flow boiling will enable the design of such systems with a higher confidence. The use of a reliable mass gauge will allow the quantification of fluid transferred and also allow for real time understanding of the amount of propellant left in either stage propellant tanks or in the depots.



Fluid flow experiment in flight frame

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Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Center Independent Research & Development: KSC IRAD

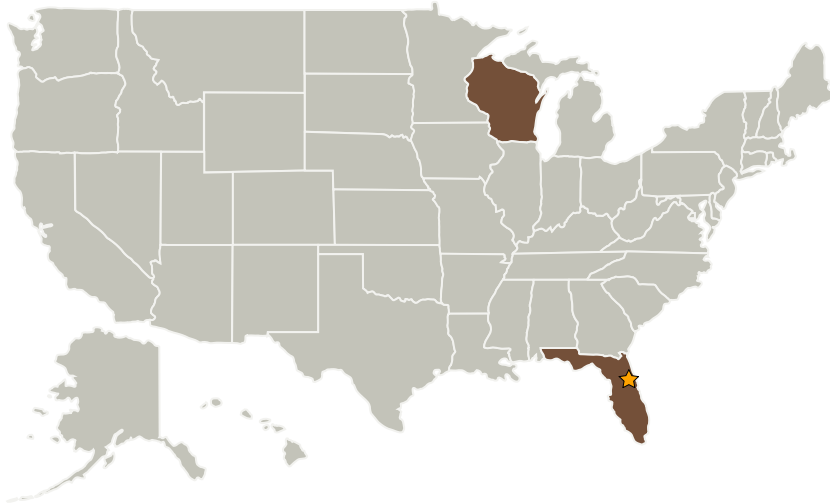
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The Department of Defense is also interested in cryogenic fluid transfer on orbit and understanding the heat transfer and boiling fluid dynamics will help the design and development of systems that perform cryogenic fluid transfer.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
Carthage College	Supporting Organization	Academia	Kenosha, Wisconsin

Primary U.S. Work Locations

Florida	Wisconsin
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Project Management

Program Manager:

Barbara L Brown

Project Manager:

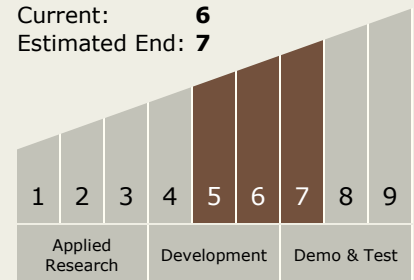
Rudolph J Werlink

Principal Investigator:

Rudolph J Werlink

Technology Maturity (TRL)

Start: 5
Current: 6
Estimated End: 7



Technology Areas

Primary:

- TX14 Thermal Management Systems
 - └ TX14.1 Cryogenic Systems
 - └ TX14.1.1 In-space Propellant Storage & Utilization

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Images



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frame

(<https://techport.nasa.gov/image/3286>)